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SINTERING OF IRON POWDER MIXTURES AND DETERMINING THEIR MECHANICAL PROPERTIES

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ABSTRACT

In this investigation, iron-based powder-metal compacts with two distinctive mesh sizes were sintered utilizing microwave heating framework. Iron-based powders of 100 mesh and 300 mesh were blended with mass portions w =2 % copper (Cu) and 2 % aluminum (Al) and also only with 2% aluminum (Al). PM samples are sintered at a frequency of 2.4GHz at 3kW and a temperature of 700 °C for 45 minutes in normal atmosphere. Mechanical properties, microstructure, and hardness were explored for this sintered component. The most elevated mechanical properties are obtained for 300 mesh, iron-based PM compacts with 2 % Cu and 2% aluminum.

KEYWORDS: Mesh Sizes, Sintering, Microwave Sintering, Microstructure & Hardness

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Original Article

INTRODUCTION

Powder Metallurgy is the branch of material science and engineering, which manages to work with metals as fine powders which can be squeezed and sintered to shape objects. It is a progression in metallurgy branch. Metallurgy is partitioned into ferrous metallurgy and non-ferrous metallurgy. Ferrous metallurgy deals with processes and alloy of iron while non-ferrous metallurgy involves process and alloy based on combinations of different metals. Iron-based metal matrix composites (MMC's) have the board use nowadays[1].

Powder metallurgy is a process of producing metals performed by heating compacted metal powders to simply beneath their liquefying point, which is called solid phases intering [12]. Sometimes few powders present in the sample can undergo liquid phase sintering such as aluminum in powder when heated above 660 degrees. In liquid phase sintering, the powder is heated above the melting point so that the liquid fills most of the pores so that the properties can be enhanced PM procedures can avoid, or reduces the need to utilize the metal removal process, in this way definitely decreasing yield loss in making a product and regularly bringing about lower costs. Powder metallurgy is likewise used to make one of a kind material difficult to get from softening or shaping in different ways. A critical result of this write is tungsten carbide (WC) which has its application as the filament in the electric bulb.

EXPERIMENTAL STUDIES

Different Powders and their Composition

Iron (300 mesh, 100 mesh), Aluminum (Al), Copper (Cu). Majority of the powders are delivered from electrolysis as the virtue is high purity i.e. up to 99.99%.

Total 4 samples are made using iron powder 300 mesh, iron powder 100 mesh, copper powder, aluminum powder and their composition is as follows. Aluminum which is expected to undergo liquid phase sintering is taken 2% as weight percentage and copper is 2% as weight percentage[2]. The chemical compositions of PM samples are given in Table 1

Table 1: Chemical Compositions of Iron-Based PM Samples (weight *w*%)

Sample No	100 Mesh Iron	300 Mesh Iron	Copper	Aluminium
1	96%	_	2%	2%
2	_	96%	2%	2%
3	98%	_	_	2%
4	_	98%	_	2%

We have taken this selected mesh size of 300 and 100, the reason behind is for comparing results of 300-100 mesh give splendid results as the difference in mess sizes is large when compared to near mesh sizes like 300-200 and so on. As the difference between two mesh size increases, we can see the variation in a better way.

Ball Milling

The powders with different compositions are weighted as per the requirement using the weighing balance and they are put together into ball milling apparatus. The metal powder mixtures of Iron and other individual metals are mixed in wet planetary ball handling for about 1hour for every case with 300 rpm speed[3]. The powders get mixed thoroughly using the balls and later the balls are removed and the powder is taken out. The time and speed of rotation depend on the nature of powders and processing parameters[4]. It is called wet ball handling since acetone is added to the metal network composites as there will be proper mixing with no bonding between two remarkable powders. Later the powder is dried and it is taken out.

Figure 2: Schematic Diagram Ball Milling Apparatus

Figure 3: Schematic Diagram Ball Milling Machine

Compaction

Compaction is a critical advance in powder preparing as it empowers the framing of free metal powders into required shapes with adequate quality to withstand till sintering is finished.. Dies are made of cemented carbide, pressed using hydraulic or mechanical presses. The segment delivered after compaction is called green compact[5].

The measure of a die is 50mm stature with the 10mm width. We have taken 8.5 grams powder out of total powder which was obtained from ball milling. The powder is taken in a round and hollow cylindrical die. The mixed powders are pressed with 650Mpa pressure on both the sides of the die[6]. The component obtained after compaction is 20mm in length and 10mm in diameter. Compaction is managed without the use of warm atmosphere. Moisture content after compaction may lead to cracking during sintering. So the sample is dried before sintering.

Sintering

Sintering is done at 700-degree centigrade so that few samples will experience fluid phase sintering and another couple of will experience solid-phase sintering. The heating rate is 25 degrees/min at a frequency of 2.4GHz, 3kW, and temperature of 700 °C for 45 minutes in normal atmosphere. Liquid phase sintering is generally expected because of the presence of aluminum (Al) which melts at 660.030 °C and the liquid flows into the pores and fills them.

Here we have done microwave sintering. Microwave sintering can offer certain favorable circumstances, such as energy efficient ecological friendly, improved density and a fine grain measure because of the speedier heating rates and the lower sintering temperature[7]. Moreover, uniform volumetric heating and littler pores in the sintered green compacts and fine microstructure are included favorable circumstances of microwave sintering[8]. Subsequently, microwave sintering will bring enhanced mechanical properties and better product execution. The microwave sintering has one of a kind points of interest over the conventional sintering forms. The fundamental contrast between traditional and microwave sintering is the warming component[1]. In conventional heating, the specimen is heated utilizing warming components like silicon bars. The heat is then exchanged to the specimen either by conduction, convection or radiation.

The main advantage of microwave sintering is the higher heating rate so that the specimens can achieve as high as 1600 °C temperature with no trouble.

Figure 5: Schematic Diagram of Microwave Furnace

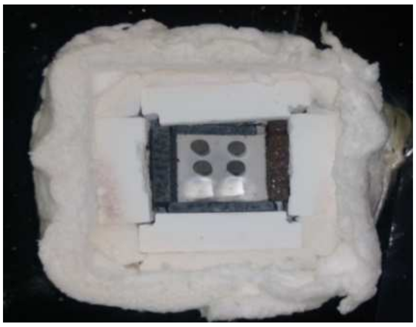


Figure 6: Schematic Diagram of Sintered Components

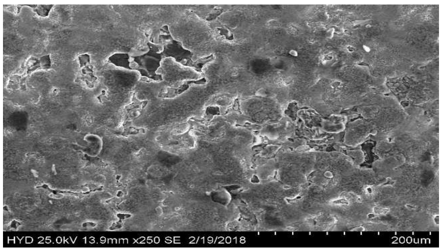
Table 2: Processing Parameters of Micro Wave Sintering

Parameter	Value
Pressure applied	650 MPa
Maximum temperature	700 °C
Power capacity	3kW
Frequency	2.4GHz
Heating rate	25 °C/min
Cooling type	Natural
Environment	Atmosphere

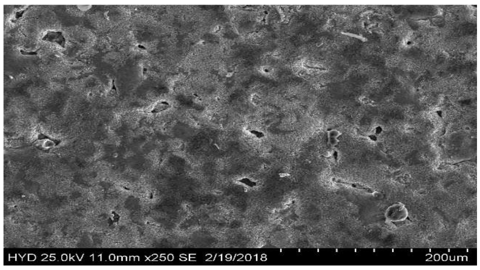
RESULTS AND DISCUSSIONS

MicroStructural Analysis

SEM pictures of samples sintered at 700 degrees can be seen in the underneath figures. During the manufacturing procedure after compaction, numerous contact areas are delivered in green bodies. Various sintering joints among powders are expected under this temperature because of powder relocation. Due to this temperature, the amplitude of vibration expands, which prompts the diffusion. More particles in the contact areas enter the range of atomic force with the goal that the bonding surface increases and finer microstructure is obtained[9]. With the increase of the bonding area, the mechanical strength of the sintered sample likewise increments.



(a)



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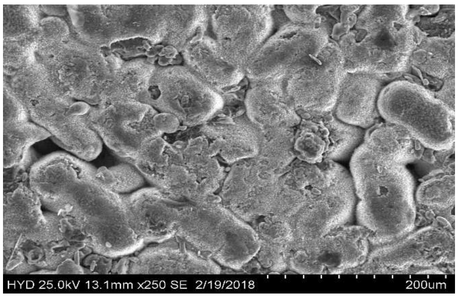

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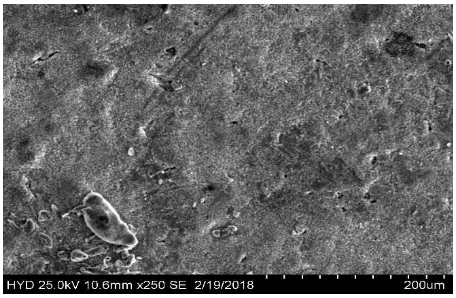

(d)

Figure 7: SEM Microstructure of Microwave Sintered Specimen:
a) 100 mesh iron+2%Cu+2%Al b) 300 mesh iron+2%Cu+2%Al
c) 100 mesh iron+2%Al d) 300 mesh iron+2%A (× 200)

Mechanical Properties of Sintered Samples

Hardness

The hardness value of the sintered samples were measured with the indentation at a load of 60 g and the dwell time of 10 seconds using a Future-Tech FM-7000-type Vickers-hardness tester and compression strength of all the samples were tested and the maximum deflection for the applied load is plotted and the brittle fracture point is also noted[10].

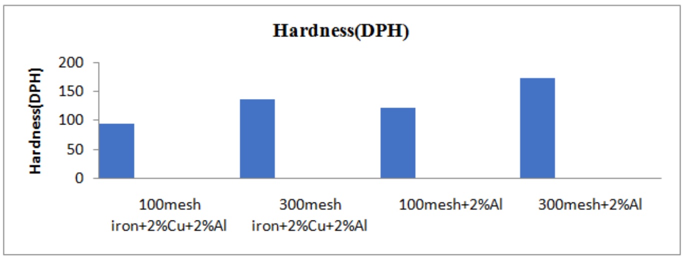

Figure 8: Micro Hardness Results for the Sintered Samples

Maximum hardness value is obtained for 300mesh iron powder with 2% copper and 2% aluminum as compared to same composition sample with 100 mesh iron powder. So we can conclude from the below table that the hardness properties can be enhanced by increasing the mesh size so that the powder will be much finer.

Compression Test

The load is applied gradually and load versus deflection is plotted. The measure of deflection per the load applied is observed[6].

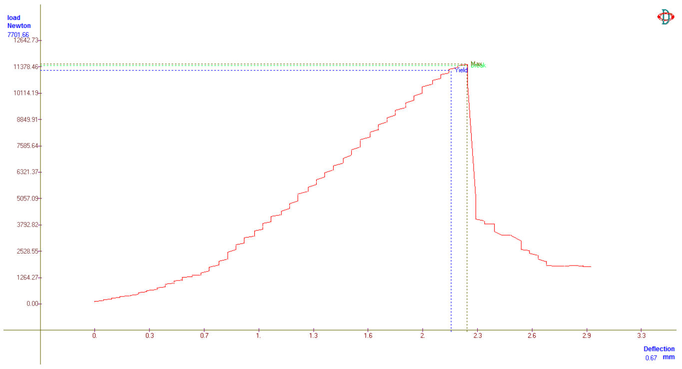

Figure 9: Compressive Strength of Sintered Samples with 100 Mesh Iron+2%Cu+2%Al

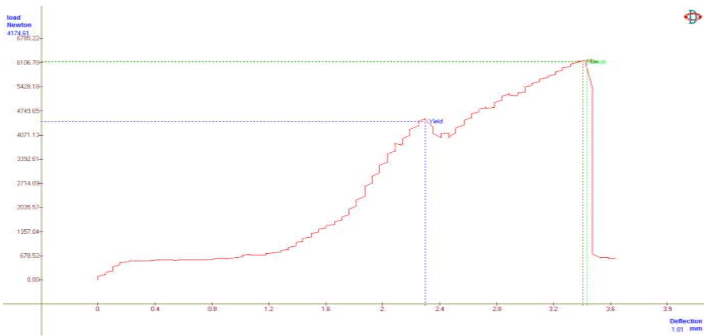

Figure 10: Compressive Strength of Sintered Samples with 300 Mesh Iron+2%Cu+2%Al

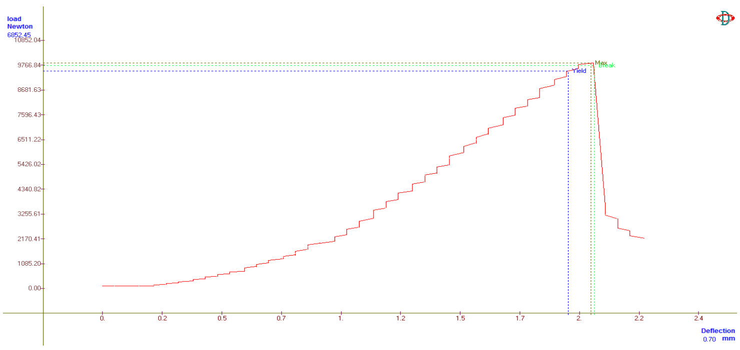

Figure 11: Compressive Strength of Sintered Samples with 100 Mesh Iron+2%Al

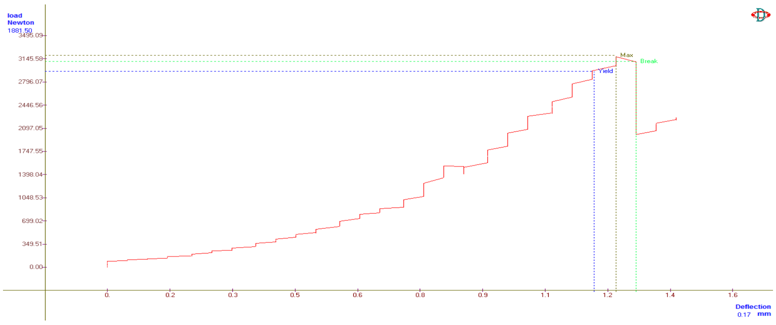

Figure 12: Compressive Strength of Sintered Samples with 300 Mesh Iron+2%Al

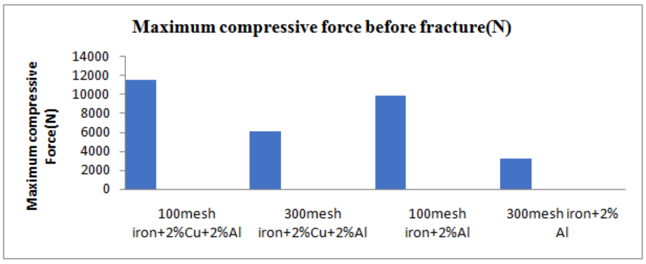

Figure 13: Maximum Compressive Force Results for the Sintered Samples

The maximum compressive force applied is more for 100mesh+2%Cu+2%Al which is 11514.95N before the fracture. The least compressive strength is obtained for the sample with 300mesh+2%Cu+2%Al which is 3197.46N which is low as the porosity of 300 mesh powder is less.

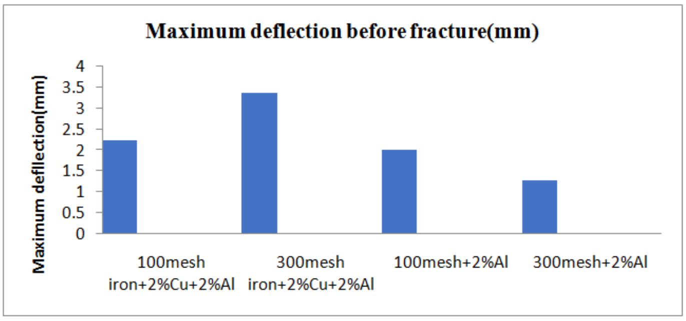

Figure 14: Maximum Deflection before Fracture for the Sintered Samples

The maximum deflection of 3.36mm for an applied compressive load is obtained for a sample with 300 mesh iron with 2%Cu and 2%Al. The minimum deflection is obtained for the sample with 300 mesh iron+2%Al.

Table 3: Mechanical Properties of PM Samples

Sample	Hardness(HV)	Deflection at Fracture(mm)	Maximum Force before Fracture(N)
100mesh iron+2%Cu+2%Al	95.30	2.22	11514.95
300mesh iron+2%Cu+2%Al	137	3.36	6138.75
100mesh iron+2%Al	122	2.0	9862.03
300mesh iron+2%Al	172	1.27	3197.46

CONCLUSIONS

Iron-based powder-metal samples with two different mesh including *w* = 2 %

Cu and 2 % Al and only with 2% Al were produced using microwave sintering [11]. From the results obtained the conclusions are as follows:

All the four samples fractured in a brittle way. The highest compressive strength was obtained for 100 mesh iron+2% Cu +2% Al and highest deflection before the fracture is obtained for 300 mesh+2%Cu+2%Al. The maximum microhardness value is obtained for 300 mesh iron+2%Al.

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